PHYSICAL TREATMENT

Milwaukee, WI - Storage

The Humboldt Avenue storage tank in Milwaukee serves approximately 231 ha (570 acres) out of a total of 7000 ha (17,300 acres) of combined sewer area in the city. The unit is designed to handle a 1.3 cm (0.5 in.) rainfall utilizing 15,140 cu m (4 million gal.) of storage. Thus, scaling up the storage volume for the entire combined sewer area for a unit rainfall analysis (2.54 cm [1.0 in.]), a total storage volume of 912,185 cu m (241 million gal.) would be required (36,37). Since this type of detention tank is equipped with mixers, the raw suspended solids concentration is usually the same as the pump/bleedback concentration. However, when the storage tank has its capacity exceeded, the mixers are not operated and the tank functions similar to a sedimentation basin. When this occurs it becomes possible for the pump/bleedback concentration to be higher than the raw discharge. The average raw flow concentration of suspended solids at Humboldt Avenue is estimated from operating records to be 192 mg/l.

The metropolitan Milwaukee area is served by two sewage treatment plants--the Jones Island Plant and the South Shore Plant. The Jones Island Plant is the major plant and handles almost all of the city's combined sewer areas and therefore, will be the subject of this feasibility analysis. The treatment consists of primary screening (instead of primary sedimentation) followed by the conventional activated sludge process, and chlorination. Primary sludge (screenings) is incinerated. The waste activated sludge is gravity thickened, vacuum filtered, and then processed into fertilizer (Milorganite). Data from 1970-1973 indicated that the plant had an average daily flow of 650,263 cu m/day (171.8 mgd) with average raw flow concentrations of 236 mg/l suspended solids, (153,517 kg/day [338,143 lbs/day]), and 232 mg/l BOD, (151,565 kg/day [333,845 lbs/day]).

Examining the concept of pump/bleedback of the contents of holding tanks serving the entire combined sewer area over various durations of time, the following percentage increases in hydraulic loading and solids loading would result.

	Percentage increases	
Bleedback duration	Hydraulic loading	Solids loading
6 hrs	561	456
12 hrs	281	229
24 hrs	140	114
48 hrs	70	57
72 hrs	47	38
96 hrs	35	28

The Jones Island Plant can handle approximately 757,000 cu m/day (200 mgd), therefore, the shortest duration of time in which the tank contents could be pumped or bledback would be 96 hours. The sludge handling capacity at the plant is 199 metric tons per day (220 tons/day), and the facilities run near design capacity at all times. If the 96 hour pump/bleedback duration was used the increase in solids loading during this period would be 28%. Obviously the only way this additional solids loading could be handled is by constructing additional solids handling facilities for this excess material.

As part of this study a sample of the mixed contents in the storage tank was taken and allowed to settle (see Section IV). The initial sample had a suspended solids concentration of 181 mg/l and the settled sludge compacted to 17,400 mg/l, occupying 0.9% of the original volume, resulting in a SVI of 50 ml/gm. If the solids were allowed to settle in this manner and the supernatant pumped or bledback to the treatment plant, the hydraulic loading on the dry-weather treatment plant would be almost identical to that described earlier for pump/bleedback of the entire contents. However, if the supernatant had a suspended solids concentration of 35 mg/l, as found in the settling tests, the increase in solids loading would be as follows:

Bleedback duration	% increase in solids loading
6 hrs	83
12 hrs	42
24 hrs	21
48 hrs	11
72 hrs	7
96 hrs	5

From this data it would appear that pump/bleedback to the dry-weather treatment plant of the supernatant from settling would be possible from a solids loading consideration over a period of more than two days. However, the limiting factor in this case would be the hydraulic loading.

The settled sludge at a solids concentration of 1.74% would constitute a volume of 8,213 cu m (2.17 million gal.) resulting from a rainfall of 2.54 cm (1.0 in.). Direct hauling of this volume of sludge would appear to be both very expensive (at 2.64¢/liter [10¢/gal.] this would amount to $217,000) and logistically be impractical. Therefore a further solids concentration step would be required.

It was found from the bench scale testing (Section VI) that centrifugation was the optimum dewatering method. It is estimated that a settled sludge of 1.74% can be increased to 30% solids through centrifugation with polymer addition. The centrate quality should have a suspended solids concentration of approximately 110 mg/l and the volume of centrate would be 7,835 cu m (207 million gal.). If this material were to be bledback, the increase in solids and hydraulic loading would not be significant. The solids at a 30% concentration from the centrifuge will amount to a volume of 363 cu m (96,000 gal.) which can be directly hauled to ultimate disposal at a reasonable cost, probably less than $10,000 as opposed to the $217,000 cost of hauling the raw sludge.

A unique consideration for Milwaukee is the fact that their waste activated sludge is converted to a commercial fertilizer known as Milorganite. Thus, even if the sewerage system and solids handling facilities were adequate to handle the solids being bledback, the effect on the ferilizer production process may be the most significant.

Cambridge, MA - Detention

The detention tank used to treat combined sewer overflows in Cambridge, MA known as the Cottage Farm facility, is actually a combination storage/chlorination and "rough" sedimentation tank. The total holding volume of the facility is approximately 4,920 cu m (1.3 million gal.) with the storage/chlorination tanks having a volume of 4,550 cu m (1.2 million gal.). The facility was designed to handle an average of 22 overflows per year ranging from 1,514 to 302,800 cu m (0.4 to 80 million gal.) with an average overflow volume of 23,845 cu m (6.3 million gal.) and a total of 15% of the overflow being retained (12). The design criteria used in choosing the 15% total capture is not fully understood. During actual testing of the facility the average overflow was 33,308 cu m (8.8 million gal.).

The detention facility receives overflow from a combined sewer area of 13,500 ha (33,333 acres); however, there are many overflow points from this system in addition to that discharging into the detention facility. There are only an additional 1,270 ha (3,136 acres) of combined sewers present which are not connected in any way to the Cambridge overflow facility. Thus, there are a total of 14,770 ha (36,470 acres) of combined sewered area out of a total of 105,624 ha (259,911 acres) of sewered area in the metropolitan area. However, many of the combined sewers are in the process of being separated.

Using the unit rainfall analysis, 2.54 cm (1.0 in.) of rainfall will result in an overflow volume (assuming 50% of the rainfall results in overflow) of 1.87 million cu m (495.3 million gal.). Extrapolating on the 15% retention volume used in the demonstration system, the resulting holding volume would be 280,000 cu m (74.3 million gal.) and the bypass volume would be 1.59 million cu m (421.0 million gal.). During the actual overflow period when the sludge samples were taken and analyzed as part of this study, the raw flow had a suspended solids concentration of 165 mg/l and the effluent concentration was 93 mg/l. The settled sludge had a concentration of 4.4%. Thus if the same removal efficiencies and sludge concentrations are applied to the unit rainfall analysis, a total of 161,191 kg (355,046 lbs) of solids would be produced and 3,671 cu m (968,000 gal.) of sludge at a 4.4% concentration would result. It must also be noted that this hypothetical example is based on the allowance that 1.59 million cu m (421 million gal.) of overflow be discharged to the receiving body of water after chlorination, and the suspended solids concentrations would be about 100 mg/l in the effluent.

There are two treatment plants, the Deer Island and Nut Island plants, serving the entire 105,624 ha (259,911 acre) metropolitan area (38). However, the Cottage Farm facility drains to an interceptor sewer leading to the Deer Island treatment plant. This plant has an average design capacity of 1,298,255 cu m/day (343 mgd), with a maximum 24 hour capacity of 2,172,590 cu m/day (574 mgd). Treatment consists of screening and grit removal (located at discrete headworks where the feeding sewers terminate), pre-chlorination, pre-aeration, primary sedimentation, and post chlorination. Sludge treatment consists of gravity thickening, anaerobic digestion and ocean disposal.

The sludge handling capacity is 1,514 cu m/day (0.4 mgd). During 1973 the average daily flow to the Deer Island Treatment Plant was 1,298,255 cu m/day (343 mgd) and the average daily sludge production was 1,200 cu m/day (0.3 mgd) or 84,600 kg (188,000 lbs).

Examining the feasibility of pump/bleedback as opposed to on-site treatment of the sludge, it is obvious that the existing plant could easily handle the additional hydraulic loading of 280,000 cu m (74.3 million gal.) in a period of 24 to 48 hours. The excess sludge handling capacity is approximately 18,160 kg/day (40,000 lb/day). Thus pump/bleedback of the tank contents at the rate of 18,160 kg/day (40,000 lbs/day) would take approximately nine days. Pump/bleedback at the rate of 22,700 kg/day (50,000 lbs/day) and 27,240 kg/day (60,000 lbs/day) would reduce the required time to seven days and six days, respectively. For overflows having lower solids concentrations the pump/bleedback concept would take proportionately less time.

From the above calculations, it appears that the concept of sludge pump/bleedback to the dry-weather treatment plant may be feasible; however, it must be noted again that only 15% of the total overflow is retained and of the 85% of the overflow still discharging to the receiving body of water, the suspended solids concentration would be approximately 100 mg/l. It was also assumed that the solids being pumped or bledback were held in suspension in the sewerage system and did not settle out before reaching the treatment plant.

Although it has just been shown that pump/bleedback from this type of system may be feasible in Cambridge from a hydraulic and solids loading standpoint, the practicality of sludge pump/bleedback has not been examined. The Deer Island treatment plant has a raw sludge volatile solids percentage of 70.4 and a digested sludge volatile percentage of 47.7. The volatile percentage of the sludge analyzed from the Cottage Farm facility was 37.6 while the suspended solids content of the settled sludge on the bottom of the detention tank was 4.4%.

Another significant concern when studying the possibility of sludge pump/bleedback that is especially significant in the case of Cambridge is the heavy metal concentrations. With the exception of mercury, the heavy metal concentrations are very high, and in some cases an order of magnitude higher than the concentrations found at other sites. Below are the heavy metal and analytical results:

	Wet basis, mg/l	Dry basis, mg/kg
Zinc	120	946
Lead	160	1,261
Copper	96	757
Nickel	16	126
Chromium	33	260
Mercury	1.55	0.01

Even if a 1:100 dilution were to occur during pump/bleedback, the synergistic effect of the heavy metals may upset treatment or digestion. Also if a majority of the heavy metals were found to be in the particulate form, then the high concentrations would be very dangerous to digestion.

Centrifugation of the settled sludge was found from the laboratory tests to be the most optimum method of dewatering with an expected solids concentration of 20% at 90% recovery and a sludge volume reduction of 89%. Thus, if the settled sludge produced from the treatment of a 2.54 cm (1.0 in.) rain, which is calculated to be 2,671 cu m (968,000 gal.) at a 4.4% solids concentration, were subjected to centrifugation, this would result in a centrate volume of 3,267 cu m (861,500 gal.) at approximately 2,500 mg/l suspended solids concentration of 20% suspended solids. Assuming that ocean disposal of sludge is permitted there would be two apparent alternative methods of solids handling. These would be 1) sludge pump/bleedback to the sewerage system and treatment plant or 2) direct disposal from the treatment site to the ocean. The only way the second choice would be considered the most attractive alternative would be if it was felt that pump/bleedback to the sewerage system would cause severe solids deposition or if the bledback sludge would receive no benefit by going through digestion and only reduce the effective digestion volume available for the normal treatment plant sludge.

If ocean disposal is not permissible it will be necessary for not only the sludge from the detention facilities but also the sludges from the dry-weather treatment plant to be disposed of on land in some form. Therefore it would be necessary to take the digested sludge now being transferred to sea and put this sludge through a further dewatering step(s) before finally disposing of it on the land. Again there are two alternatives if ocean disposal is not permitted. These are 1) sludge pump/bleedback to the sewerage system and treatment plant with the sludge being thickened, digested, dewatered and disposed of with the normal treatment plant sludge and 2) on site sludge centrifugation followed by disposal with the centrate bledback to the sewerage system. The objectives to the first alternatives are the same as in the previous cases. However, assuming pump/bleedback is feasible, the comparison between the two alternatives is whether it is more economical to re-thicken, digest, and dewater the sludge at the treatment plant or to centrifuge the sludge at the detention tanks and dispose of it. Also, if the sludge were to be sent back to the dry-weather treatment plant there is the possibility that some of the grit would not be removed by the existing grit facilities and therefore additional classification equipment may be required. It is estimated that the operating costs for centrifugation would be 84¢/cu m (0.32¢/gal.) or 2¢/kg (0.91¢/lb). This cost does not include amortization of the capital equipment costs. The operating cost would then have to be compared to the handling costs at the treatment plant and the lesser chosen. This type of comparison assumes, however, that land disposal of the centrifuged sludge (at 37% volatile solids) would be permissible without any digestion or oxidation step such as lime stabilization. It is estimated that the land disposal costs of the dewatered sludge would be approximately the same for both alternatives. Some recent land (or alternative) disposal method costs are listed below (39).

Method	Cost range ¢/kg	Cost range ¢/lb
Pipeline to land	0.55 - 2.20	0.25 - 1.0
Trench to land	2.20 - 0.50	1.0 - 2.5
Rail to land	3.30 - 11.0	1.5 - 5.0
Drying	3.3 - 5.5	1.5 - 5.0
Compost	0.55 - 1.1	0.25 - 0.5
Incineration	4.4 - 5.5	2.0 - 2.5

Philadelphia, PA - Screening

Studying the feasibility of on site treatment compared to sludge pump/bleedback for the treatment system being tested in Philadelphia requires a great deal of data synthesis since the flow capacity and drainage area of the study site is so small compared to the large combined sewer area in the City of Philadelphia. The 23 μ microscreening unit in operation has an average design capacity of 1000 l/min/sq m (25 gpm/ft^2) and serves an area of 4.5 ha (11.1 acres). The entire sewered area of metropolitan Philadelphia is 92,600 ha (228,600 acres) with the combined sewer area being 64,800 ha (160,000 acres). Using a unit rainfall analysis (1.0 inch [2.54 cm]) with the assumption that half of the rainfall results in overflow, the total overflow volume treated would be 8,221,020 cu m (2,172 million gal.). From actual operating data (40) it is estimated that a backwash sludge volume of 520,000 cu m (137 million gal.) would be produced at a suspended solids concentration of 2,000 mg/l resulting in a dry solids production of 1,045,000 kg (2,300,000 lbs).

The metropolitan Philadelphia area is served by three sewage treatment plants--the Northeast, Southeast and Southwest plants. The Northeast plant, which has secondary treatment, has a design capacity of 662,375 cu m/day (175 mgd) and in 1972 the average daily flow was 681,300 cu m/day (180 mgd). The sludge from the plant is digested and then barged to sea for ultimate disposal. During 1972 the average daily sludge production was 2,157 cu m/day (0.57 mgd) with an average suspended solids concentration of 4.4% (94,962 kg [209,167 lb]). The other two treatment plants consist of only primary treatment with a cumulative design flow rate of 1,029,520 cu m/day (272 mgd), and an actual cumulative flow rate of 991,670 cu m/day (262 mgd) during 1972. The sludge from the Southeast plant is piped to the Southwest plant where it is digested, centrifuged, and then lagooned prior to barging. During 1972 the cumulative sludge production was 3,255 cu m/day (0.86 mgd), with an average suspended solids concentration of 5.4% (175,850 kg [387,310 lbs]). The combined solids handling capacity of the plant is estimated to be about 20% higher than actually used in 1972. However, there presently exists a restriction against increasing the amount of sludge barged to sea, which in effect means that any additional sludge produced by the City of Philadelphia will have to be disposed of by an alternate means.

Studying the feasibility of sludge pump/bleedback to the Philadelphia treatment plants for digestion purposes, with alternate disposal being other than to the ocean, the increases in daily solids production are as follows for various pump/bleedback periods:

Pump/Bleedback duration days	% increase in solids
1	385
3	127
5	76
7	54
9	42

It would appear that the shortest pump/bleedback duration possible, with a slight overload on the dry-weather treatment plant, would be at least nine days. This length of time would allow the possibility of odoriferous conditions to occur and the solids would surely settle out in the backwash holding tank (unless some means of aeration were implemented). The settling of the solids would have no significant effect (other than a higher pump/bleedback concentration when the bottom sludge was being removed) provided that provisions for the removal of the sludge were made.

Once the sludge is digested at the treatment plant, the sludge in excess of the present daily production must be split off and disposed of in some other manner than ocean disposal. Regardless of the alternate type of disposal chosen some type of dewatering step will most likely be utilized to minimize disposal transportation costs. It is calculated for Philadelphia's annual rainfall of about 102 cm (40 in.) that the weight of sludge produced from combined sewer overflow treatment by microscreening would be approximately 38% of the total annual sludge produced by the existing treatment plants. Even if only half the annual overflow in the CSO area were treated, the weight of sludge would still be 19% of Philadelphia's annual production.

Since these additional dewatering facilities will be required either at the combined sewer overflow sites themselves or on the grounds of the conventional treatment plants, the major factors in deciding where the solids handling facilities should be located would be the effect of the extra solids on the dry-weather plant (primary sedimentation sludge removal facilities), the necessity of digestion, and the cost of many separate sludge handling facilities compared to one or two facilities located at the dry-weather treatment plants.

The obvious effect on the dry-weather treatment plant is the increased solids loading resulting in an increased sludge volume which must be handled, thus reducing the effective processing time for the conventional plant dry-weather sludges. In the case of the combined sewer overflow sludge at the Philadelphia test site, as is the case for most sites, the volatile percentage of the suspended solids was very low (25%). From this fact it can be seen that conventional aerobic or anaerobic digestion will have little effect on reducing the volatile content of this sludge. Thus, pumping or bleeding the sludge back to the treatment plant will only displace volume in the digesters and reduce the effective digestion period of the conventional plant solids.

One method of reducing the volume of wet weather sludge that would utilize dry-weather sludge digestion facilities would be to degrit the wet weather sludge prior to digestion. By degritting, much of the inert material (that not amenable to digestion) could be separated prior to digestion, thus greatly reducing the ultimate volume of wet weather sludge to be handled. Obviously, the optimum location for degritting this sludge would be at the wet weather treatment site itself, prior to pump/bleedback into the sewerage system. However, in actual application it would have to be determined if the highly inert wet weather sludge were discharged into the sewerage system and diluted, would the inert material in fact be removed by the conventional grit removal facilities at the dry-weather plant.

Regarding the matter of cost, it is obvious in the case of solids handling that the larger the capacity of the facility, the lower the unit cost will be. However, in this particular case, if it is assured that digestion is not required for the combined sewer overflow produced sludges, it would still be necessary to increase the sizes of the digestion equipment at the conventional treatment plant unless degritting facilities were constructed, since the combined sewer overflow sludge would be mixed with the conventional plant solids. If on-site treatment of the solids were utilized, only thickening and centrifugation or vacuum filtration would be required. The solids could then be transported to ultimate disposal.

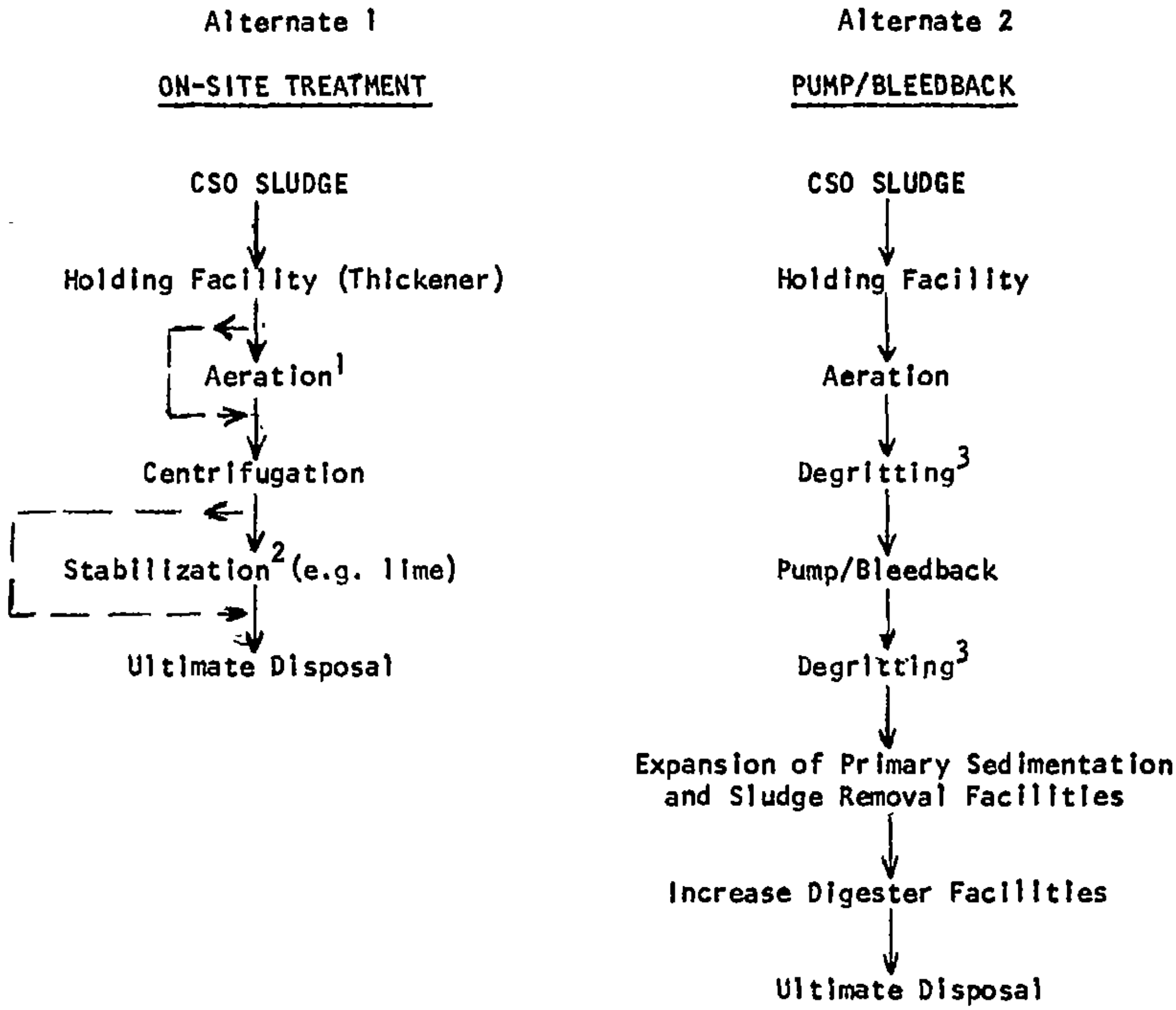
The thickening process could serve a dual function by acting as a holding tank (or vice versa), thus reducing the flow rate to the dewatering process and resulting in a smaller capacity unit. Also, an economic study could be performed to determine if a centrally located dewatering facility, with the sludges from the combined sewer overflow sites being pumped to this site, could be constructed and operated at a lower cost than discrete on-site units.

Thus for the case of Philadelphia, a large city with a high percentage of its drainage area being served by combined sewers, a pump/bleedback of solids produced from combined sewer overflow treatment does not appear to be the obvious solution for handling the wet weather sludges. The optimum solution can only be determined by comparing the specific costs of on-site treatment facilities versus the facilities needed for pump/bleedback. Figure 42 illustrates the requirements of either alternative.

PHYSICAL CHEMICAL TREATMENT

Racine, WI - Screening/Dissolved-Air Flotation

The combined sewer overflow facilities in Racine, WI from which sludge samples were obtained for this study utilize the screening/dissolved-air flotation process. The facilities consist of two adjacent but separate treatment plants having capacities of 166,540 cu m/day (44 mgd) and 52,990 cu m/day (14 mgd) for a combined capacity of 219,530 cu m/day (58 mgd). The units serve a combined sewer area of 190 ha (470 acres) and are designed to handle a 1.27 cm/hr (0.5 in./hr) rainfall. The floated scum from the flotation units plus the screen backwash is retained in holding tanks until after the level in the interceptor sewer leading to the treatment plant drops to such a level that the tanks can be bled into the interceptor.



1. Depending on the design rate of the centrifugation facility.
2. May or may not be needed, depending on regulations.
3. Degritting facilities only required in one of the two locations shown.

Figure 42. Comparison of the requirements of on-site treatment of wet weather sludges versus pump/bleedback to the dry-weather treatment plant

The existing dry-weather treatment plant serving the City of Racine consists of full primary treatment rated at 87,055 cu m/day (23 mgd) and secondary treatment (activated sludge) rated at 45,420 cu m/day (12 mgd). During the calendar year of 1973 the average daily flow was 91,597 cu m/day (24.2 mgd). Waste activated sludge is returned to the primary sedimentation tanks where it is settled out with the primary sludge and this sludge is then anaerobically digested and vacuum filtered. The sludge is then disposed of at a landfill site. The total volume of the two stage digestion system is 7,570 cu m (2 mg). In 1973 an average of 341 cu m/day (90,090 gal./day) of sludge at a solids concentration of 7.48% resulting in 25,450 kg/day (56,080 lb/day) of dry solids was produced.

Scaling up the screening/dissolved air flotation units to treat the entire combined sewer overflow area (284 ha [701 acres]) for a 2.54 cm (1.0 in.) rainfall, the volume of overflow is estimated to be 35,957 cu m (9.5 million gal.).

From operating experience at the combined sewer overflow treatment sites in 1972 and 1973 it is estimated that 1,798 cu m (0.47 million gal.) of sludge at a suspended solids concentration of 8,400 mg/l would be produced. It should be noted that the low solids concentration is caused by mixing the floated scum and screen backwash. The floated scum alone can be expected to have a solids concentration of 2.4%; however, the dilute screen backwash (<3000 mg/l) causes the resultant sludge in the holding tanks to be of very low solids concentration.

Examining the feasibility of sludge pump/bleedback in Racine, it is obvious that the 1,798 cu m (0.47 million gal.) of sludge at a concentration of 8,400 mg/l could be handled by the dry-weather plant over a one to two day period with no significant increase in flow. However, at the present time the average daily flow to the treatment plant is greater than design, so even though the flow would be a small percentage increase, it would be flow above the capacity of the plant. From a solids loading standpoint, the bleedback of 14,982 kg (33,000 lbs) of solids would represent the following percentage increase:

Pump/Bleedback Period, days	% Increase in solids
1	59
2	29
3	20
4	15
5	12
6	10

From the above data it would appear that sludge pump/bleedback would be feasible over a period of greater than two days. However, at the present time the digestion and solids handling capacity of the Racine treatment plant is rated at 22,700 kg/day (50,000 lbs/day). Therefore, the plant is already operating above capacity and theoretically could not handle any more solids, thus necessitating on-site treatment of the solids. However, the Racine treatment plant is scheduled to undergo expansion in the near future and the possibility of utilizing sludge pump/bleedback of the combined sewer overflow sludge would be greatly improved if the new solids handling facilities had the capacity to handle these extra solids.

Making a rough economic comparison of the costs (capital and operating) of building additional solids handling facilities at the existing dry-weather plant versus building a centralized wet-weather sludge facility, the data generated by Burd (21) in 1968 can be used. Although these costs are outdated, they are valid for use in making a relative comparison assuming equal escalation of all costs. The additional dry-weather sludge handling facilities (including thickening, digestion, dewatering and landfilling) are estimated to have an annual capital and operating cost of 1.1-5.5¢/kg dry solids ($10-50/ton) with an average cost of 2.8¢/kg ($25/ton). This cost does not reflect any additions for degriting facilities which may be necessary. However, if degriting facilities were used, the amount of solids sent on to further digestion and dewatering would be reduced, thus lowering those costs.

A centralized wet weather solids handling facility consisting of thickening, centrifugation and landfilling is estimated to have an annual capital and operating cost of 0.8¢-5.0¢/kg dry solids ($7.5-$45/ton) with an average cost of 2.0¢/kg ($18/ton). Although the cost for on-site treatment of the solids is shown to be 0.8¢/kg ($7.5/ton) cheaper than construction and operation at the dry-weather plant, it must be realized that no provisions were made for stabilizing the highly inert (only 40% volatile) wet weather sludges. If stabilization is required, then the associated costs for this process must be considered.

If on-site treatment were utilized for solids handling, it is calculated that by subjecting the screen backwash to thickening, the net volume of sludge to be handled can be reduced to 378 cu m (0.1 million gal.) with the supernatant from thickening being returned to the sewage treatment plant. This 378 cu m (0.1 million gal.) at a suspended solids concentration of 4.1% would be dewatered by centrifugation to an expected cake solids of 11-33% at 93-96% corrected recovery. At the expected cake solids the ultimate sludge to be disposed of would be reduced to a volume of 50-150 cu m (0.013-0.04 million gal.). Over the course of a year, based on an estimated 75 cm (30 in.) of rainfall, the total volume of sludge to be hauled to land disposal would be 1500-4500 cu m (0.4-1.2 million gal.) Of course the volume of sludge to be handled would be proportionately less for any amounts generated by less than 75 cm (30 in.) of rainfall if it were decided to treat less.

Milwaukee, WI - Dissolved-Air Flotation

The dissolved-air flotation combined sewer overflow treatment site in Milwaukee, (the Hawley Road site) is a 18,925 cu m/day (5 mgd) pilot unit and served as the forerunner of the system constructed in Racine, WI. The system does in fact contain a screening unit, as in Racine, but since this was a pilot facility, the screen backwash flows directly to a sanitary sewer near the treatment site. Therefore, the screen backwash was not mixed with the floated scum from flotation and was not part of the laboratory tests, hence this case is being studied as only dissolved air flotation. This assumption is certainly valid since the screenings, in a full scale application, would probably have a very high grit content and could be elutriated and disposed of directly to a landfill site. However, as seen by the Philadelphia discussion earlier, if a final study were being performed to decide which alternative would be optimum, serious consideration would have to be given to the volume and weight of solids in the backwash.

The sewage treatment facilities in Milwaukee were described earlier in this section, and of course apply to this analysis also. In summary, the average daily flow at the treatment plant is 651,020 cu m/day (172 mgd) with a daily solids loading of 153,517 kg/day (338,143 lb/day) and the waste activated sludge from secondary treatment is ultimately marketed as fertilizer.

Using the unit rainfall analysis as the basis for comparison, it is calculated that a 2.54 cm (1.0 in.) rainfall over the 7,000 ha (17,300 acres) of combined sewer area would result in a treated overflow volume of 885,690 cu m (234 million gal.). From this it is estimated that the flotation process would produce about 3,200 cu m (0.85 million gal.) of sludge at a solids concentration of 3.65% for a total dry weight of 116,919 kg (257,630 lbs). The calculated increase in solids loading at the Jones Island treatment plant for various pump/bleedback durations would be as follows:

Pump/bleedback period days	% increase in solids
1	76
2	38
3	25
4	19
5	15
6	13
7	11

Based on the premises that the sludge could be transported to the treatment plant in the sewerage system without settling, and that the solids could be removed at the treatment plant, then the slight excess capacity for solids handling at the Jones Island treatment plant would make pump/bleedback feasible over approximately a four day period. Again it is noted that the screen backwash has not been considered.

However, the logistic feasibility of pumping or bleeding back this sludge becomes questionable when it is considered that the sludge has already achieved a solids concentration of 3.65% in the flotation process. It appears to be somewhat a wasted effort to dilute these solids in the sewerage system and then use space in the gravity thickener at the Jones Island treatment plant to re-thicken these solids to their original state. It should also be noted that the Jones Island treatment plant utilizes grit chambers followed by screening, rather than primary sedimentation, and the solids pumped or bled back that were removed in screening would be subjected to incineration. The fuel value of the floated scum at Hawley Road was determined to be 1,654 cal/gm (2996 BTU's/lb), which is not especially good for incineration purposes. However, if upon further study it was found that the pumped or bledback sludge going to and being removed in the final clarifiers contained significant concentrations of nitrogen and phosphorus, then the sludge may prove advantageous in the production of Milorganite. However, again it is found that the volatile solids percentage of the sludge is on the low side, 32%, and this casts doubt upon the quality of this material as a fertilizer. It also indicated that the sludge may have a high grit content and therefore expansion of the existing grit removal facilities would probably be required if the sludge were to go to the dry-weather plant.

The type of on-site treatment chosen as best in the laboratory testing was direct centrifugation of the floated scum. The bench scale tests indicated that a 20% cake solids could be achieved, with a centrate suspended solids concentration of 200 mg/l through centrifugation. The cake solids would have to be hauled to a land site for ultimate disposal.

San Francisco, CA - Dissolved-Air Flotation

The combined sewer overflow prototype unit in San Francisco is similar to those found in Racine and Milwaukee, WI with the exception that screening does not precede flotation. The test unit serves an area of 68 ha (168 acres) while the entire drainage area of the city (all of which is served by combined sewers) is 12,150 ha (30,000 acres). Applying the unit rainfall analysis an estimated overflow volume of 1,540,500 cu m (407 million gal.) would be produced. Estimating the volume and solids concentration of the sludge produced for this test site was very difficult. The grab sample taken of the floated scum during this project had a suspended solids concentration of 2.25%, however, operating data from the San Francisco sites indicates that a float concentration of 1000-2000 mg/l can be expected. Also, the combined sewer overflow at the San Francisco site has a very low average raw suspended solids concentration and thus the net suspended solids removals are only in the range of 20 mg/l.

For a volume of 1,540,500 cu m (407 million gal.) this 20 mg/l would amount to 30,821 kg (67,800 lbs) of solids. At a concentration of 1,000 mg/l this would be a volume of 30,772 cu m (8 million gal.) and at a 2.25% concentration the volume would be 1,363 cu m (0.36 million gal.).

The metropolitan San Francisco area is served by three separate primary sewage treatment plants with a total design capacity of 1,135,500 cu m/day (300 mgd). An estimated 57,000 kg (125,000 lbs) of solids are gravity thickened, anaerobically digested, and vacuum filtered (to a solids concentration of >25%) before being disposed of in a landfill or used as a soil conditioner. The volume of sludge produced from combined sewer overflow sites (1,363 or 30,772 cu m [0.36 to 8 million gal.]) could be pumped or bled-back to the treatment plants without any hydraulic problems. Although the present solids handling facilities at San Francisco are running at capacity, pump/bleedback of the 30,831 kg (67,880 lbs) of solids over a two to three day period would only increase the loading on the solids handling facilities by a matter of about 15%. However, an especially important aspect of pump/bleedback which must be considered in the case of San Francisco is the solids removal efficiencies being achieved at the treatment plant. In San Francisco, the weighted average removal of suspended solids is approximately 50%. Assuming these removal efficiencies held true during periods of sludge pump/bleedback, then half of the solids which were removed at the combined sewer overflow facilities would escape in the effluent from the dry-weather treatment plant.

Ironically, although the hydraulic and solids loadings appear to be feasible in the case of the San Francisco test site, the low suspended solids removals achieved at the dry-weather treatment plant would make solids pump/bleedback impossible. Thus for San Francisco it would appear that on-site treatment is necessary in order to make the effort put into treating the combined sewer overflow worthwhile. The on-site treatment process found to be best for San Francisco consisted of thickening followed by vacuum filtration. Since the solids produced from the treatment of the combined overflow must be stored on-site until the flow rate in the sewer decreases if pump/bleedback is going to be utilized, the thickener requirements are not really an extra cost. However, if the concentration of the flotation scum can be consistently in the vicinity of 2% rather than 1,000-2,000 mg/l, the size of the holding tank could be greatly reduced. It is estimated that utilizing vacuum filtration on the floated scum in excess of 2%, a cake of 18% solids could be achieved. This would result in net volume of <171 cu m (45,000 gal.) of sludge to be hauled away. If the scum from flotation is very dilute and must be thickened to 0.5-1.5% prior to vacuum filtration, it is estimated that the cake solids produced would be 10-20%. This would result in a volume for disposal of 150-300 cu m (40,000-80,000 gal.).

BIOLOGICAL TREATMENT

Kenosha, WI - Contact Stabilization

The combined sewer overflow treatment system tested in Kenosha is significantly different than those discussed earlier in this report because it is located on the same grounds as the existing conventional dry-weather treatment plant. In fact, since the system utilizes biological treatment it depends on the dry-weather plant as a source of active biomass. Waste activated sludge from the dry-weather treatment plant is continuously fed through the combined sewer overflow treatment system stabilization tank, where it has a hydraulic retention time of approximately five days before going on to flotation thickening. When the combined sewer overflow treatment system is put into operation, the contents of the stabilization tank are pumped to a contact tank (mixed liquor aeration) instead of to thickening. A complete description of the system operation can be found in Appendix A.

The conventional dry-weather treatment plant at Kenosha is a 87,055 cu m/day (23 mgd) activated sludge process. Waste activated sludge, approximately 314 cu m/day (0.083 mgd) at a solids concentration of 1.47% (approximately 4,540 kg/day [10,000 lb/day]) is flotation thickened to about a 5% solids concentration before going on to anaerobic digestion. The digested solids are then further dewatered by means of a filter press.

The total daily loading on the digesters, primary and waste activated sludge combined, is 190 cu m/day (0.05 mgd) resulting in a dry solids weight of 11,035 kg (24,307 lbs). When the additional loading of solids due to combined sewer overflow treatment is considered, the stabilization tank must be examined as the source of these solids. This is due to the fact that the contact stabilization process does not utilize any primary sedimentation, therefore all solids, both particulate matter and solubles converted into biomass, settle out in the final clarifier as part of the sludge blanket. This sludge is then returned to the stabilization tank as part of the waste sludge. The excess solids produced as a result of the treatment of the combined sewer overflow will either cause an increase in the blanket depth of the final clarifier necessitating an increase in the flow rate to the stabilization tank, or cause the sludge blanket, and thus the sludge pumped to the stabilization tank, to have a higher solids concentration.

The entire sewered area of Kenosha is 3,735 ha (9,222 acres) of which 539 ha (1,331 acres) are combined. Assuming the excess flow can be conveyed to the treatment plant and that adequate combined sewer overflow treatment facilities can be constructed, it is estimated that a 2.54 cm (1.0 in.) rainfall would result in an excess flow volume of 68,130 cu m (18 mg). From actual operating data in Kenosha (36) it is estimated that the treatment of this volume would produce 23,850 kg (53,530 lbs) of solids which constitutes a volume of 2,384 cu m (630,000 gal.) at a concentration of 1%. Also, the sample of the sludge analyzed as part of this study had a relatively high volatile solids percent (63.0), thus necessitating digestion before going to land disposal.

The alternatives available in the case of Kenosha are not really whether pump/bleedback is feasible or not, but rather whether the existing form of sludge handling should be expanded and utilized or whether an alternate method should be employed for sludge handling. This is the case for centrally located wet weather systems as opposed to satellite treatment systems which face the pump/bleedback question. Therefore, there appears to be three actual alternatives; 1) enlarge as necessary the existing flotation thickening, digestion, and dewatering facilities, 2) build completely separate thickening and dewatering facilities (assuming digestion is not required) or 3) use some of the existing sludge handling facilities and also construct some additional new facilities.

Assuming that this excess sludge must be subjected to digestion, and based on the fact that the existing digesters are already at capacity, it appears obvious that additional digesters would be required. However, 1972 operating data from the Kenosha treatment plant indicated that the flotation thickeners were only operated at an average daily loading of 20 kg/day/sq m (4.1 lb/day/ft^2) (13). If it is estimated that loadings of up to 100 kg/day/sq m (20 lbs/day/ft^2) are possible (13), then the existing thickeners could easily handle the additional solids within two days. Thus, only additional digesters would be needed since the filter press facilities are also capable of handling the excess solids.

If digestion is not required, it would appear from the bench scale testing done that thickening followed by vacuum filtration or centrifugation would be the optimum combination to utilize. With either procedure a cake solids concentration of at least 15% should be attainable. This would reduce the volume of sludge to be ultimately disposed of from 2,384 cu m (630,000 gal.) down to approximately 159 cu m (42,000 gal.). Again, as in the case above, the existing flotation equipment could be utilized with new dewatering facilities provided. It should be noted here that if the thickened solids could go straight to dewatering prior to disposal, the feasibility of utilizing the excess filter press capacity for dewatering the undigested sludge should be tested and the results compared to those obtained in the tests for dewatering undigested sludge by means of vacuum filtration and centrifugation. Another aspect of the Kenosha system which could possibly render digestion unnecessary is the fact that the stabilization tank also serves as an aerobic digester. Therefore, if the excess solids produced as a result of combined sewer overflow treatment were withdrawn from the stabilization tank over a period of more than two days it can be expected that a significant destruction in the volatile solids concentration may occur.

The alternative of building all new facilities does not seem practical in any situation. The fact that excess capacity is available in the existing flotation thickeners, coupled with the amenability of biological sludges to flotation thickening, makes the use of these facilities imperative. The only decision to be made, if in fact complete combined sewer overflow treatment were carried out in Kenosha, would be whether to expand the existing digestion facilities or to build separate mechanical dewatering facilities (vacuum filtration or centrifugation) or to use the existing filter press facilities if possible. From an economic standpoint, it appears possible in Kenosha if satisfactory digestion were accomplished in the stabilization tank, that the existing flotation thickeners and filter press would be sufficient to handle the extra wet weather solids and no new facilities would be required.

New Providence, NJ - Trickling Filter

Of all the combined sewer overflow sites studies, the trickling filter system tested in New Providence was the most unique since the concept of solids bleedback is utilized as part of the normal mode of operation for this installation. As discussed in detail in Appendix A the two trickling filters which normally run in series during normal flow periods are converted to parallel operation during periods of high flow. The solids settling in the final clarifier are recycled to the primary sedimentation tank where they settle out with the primary solids. This combined sludge is then drained to a sewer which flows to a larger sewage treatment plant downstream. Apparently the downstream treatment plant has the capacity to remove and handle the solids produced at the New Providence facility.

This facility does not really treat combined sewer overflow, but actually handles the high flows caused by infiltration into the sanitary sewers. Therefore, since the present plant can handle the high flows experienced during rainfall periods, it is not forecasted that any appreciable increase in flow can be expected in future years. Thus, it is not applicable in this case to compare on-site treatment versus bleedback since the existing form of bleedback appears to be functioning as planned and will continue to be used in the future. If this type of arrangement were to be utilized at another site not being able to discharge the excess solids to another treatment facility, feasibility studies for the optimum means of on-site thickening, digestion and dewatering would be required. However, these feasibility studies would be conducted in the same manner as those normally associated with dry-weather treatment plants.

SUMMARY

After reviewing the eight combined sewer overflow sites which were part of this study for the feasibility of utilizing pump/bleedback of treatment produced solids as compared to on-site treatment, it is apparent that no specific conclusions can be drawn for all cases, but instead each case must be studied on an individual basis. In general, it does not appear possible to pump or bleedback the solids produced from the treatment of an entire combined sewered city to the dry-weather treatment plant. This is due primarily to the possibility of solids settling in the existing sewerage system and to the overloading of the dry-weather treatment plant sludge handling facilities. Also, in cases of combined sewer overflow storage, it may not be possible from a hydraulic consideration to pump or bleedback the entire stored contents to the dry-weather treatment plant. These facts become especially critical when the dry-weather plants under study are near design capacity for either hydraulic or solids handling facilities. If only a portion of a city's drainage area is served by combined sewers, then controlled pump/bleedback of the combined sewer overflow treatment produced sludges may be possible.

In most cases where on-site treatment of the sludges produced from combined sewer overflow treatment is utilized, the hydraulic and solids loadings resulting from the pump/bleedback of centrates, supernatants, and filtrates from sludge thickening and dewatering processes such as flotation, centrifugation, or vacuum filtration will be possible. However, in many cases pump/bleedback of the concentrated sludges has been shown to be a problem. Table 33 summarizes the increase in solids loading on dry-weather treatment plants resulting from the treatment of 1.2 cm (0.5 in.) of runoff. The amounts of sludge were determined from the data generated at the existing combined sewer overflow treatment demonstration systems. The figure only represents those sites where satellite treatment was tested.

A very important consideration which can easily be overlooked when comparing the concept of pump/bleedback versus on-site treatment is the efficiency of removal at the existing dry-weather treatment plant. It is not possible to accurately estimate, without actual field testing, what effect pump/bleedback will have on the percentage removals at the dry-weather treatment plants. However, even if it is assumed that the percentage removals obtained during normal operating periods hold true during the pump/bleedback periods when the flow rates increase, the percentage of contaminants ending up in the receiving body can still be significant. For example, if a combined sewer overflow treatment site achieves 70% removal of suspended solids and these solids are pumped or bled back to a treatment plant achieving 80% removal of suspended solids, the net removal of the combined sewer overflow treatment site is:

$$(0.70) \times (0.80) = 0.56 \text{ or } 56\%$$

This can greatly increase the true cost of combined sewer overflow treatment when studied on a cost per mass removal basis.

Another example analogous to the above would be the effect of pump/bleedback which caused effluent quality to decrease only a slight amount. Using the City of Milwaukee as an example, if pump/bleedback raised the average raw flow rate

Table 33. SUMMARY OF SOLIDS INCREASES AT DRY-WEATHER TREATMENT PLANTS FOR PUMP/BLEEDBACK OF CSO PRODUCED SLUDGES FROM 1.25 cm (0.5 in.) OF RUNOFF

Pump/ Bleedback duration, days	Milwaukee, WI storage (total contents)	Milwaukee, WI storage (only settled sludge)	Cambridge, MA Storage	Philadelphia, PA microscreening	Racine, WI S/DAF	Milwaukee, WI DAF only
	% Increase	% Increase	% Increase	% Increase	% Increase	% Increase
0.5	229	42	294	770	118	152
1.0	114	21	138	385	59	76
2.0	57	11	60	193	29	38
3.0	38	7	34	127	20	25
4.0	28	5	21	97	15	19
5.0	23		14	76	12	15
6.0	19		8	63	10	13
7.0	16		5	54	9	11
8.0	14			48	7	10
9.0	12			42	6	8

by 10% for a period of 3 days and the average effluent suspended solids concentration increased by only 2 mg/l, the following additional loading of solids would enter the receiving body of water:

651,020 cu m/day [172 mgd]) (1.1) (3 days) (2 mg/l) (constants) =

(4300 kg [9500 lbs])

Thus, over a three day period the increase of 2 mg/l in effluent concentration would have an actual increase loading to the receiving body of water of 4300 kg (9500 lbs) which is significant.

Other important considerations that must be made when studying the concept of pump/bleedback are 1) the possibility of toxicity of heavy metals or other elements to the associated dry-weather treatment plant biological processes 2) the need and practicality of subjecting the combined sewer overflow solids, which appear to have a low volatile percentage to digestion, and 3) the possibility of overloading the grit removal and primary sludge removal facilities, thus necessitating additional degritting facilities either at the head end of the treatment plant or at the overflow treatment site itself.

Although this section has analyzed the feasibility of pump/bleedback of CSO sludges versus on-site treatment, its purpose has only been to demonstrate the voluminous ramifications (specifically for the requirement of additional facilities) and problems resulting from either alternative. Specific answers to determine the best method for each municipality requires a thorough economic study of all the alternatives available. No general recommendations can be made.

SECTION VIII

DISCUSSION

The characterization data presented in Section V of this report has unquestionably demonstrated the magnitude of the problem posed by the sludge residuals generated as a result of combined sewer overflow treatment. The data has shown that the volumes and characteristics of these residuals vary widely. The pump/bleedback of the entire amount of residuals to dry-weather treatment facilities does not seem to be a promising method of disposing these residuals as discussed in Section VII. However, partial pump/bleedback in specific situations may be possible. Therefore, on-site handling and treatment of these residuals is necessary for a satisfactory solution to this important problem. The treatability test results (Section VI) have demonstrated that several dewatering techniques may be applicable for the on-site thickening of the various residuals.

Dilute sludges such as the retained contents of storage/settling treatment or screen backwashes require a concentration step before any thickening treatment may be utilized. Therefore, for CSO treatment sites employing a combination of storage and screening/dissolved-air flotation treatment, perhaps a more logical and economical step would be to keep the dilute tank residuals and screen backwash separated from the concentrated residuals such as settled solids or flotation scum. After concentration of the dilute residuals by sedimentation with or without chemicals, the clarified supernatant may be best discharged to the sanitary sewer or the receiving body of water while the clarified sludge can then be combined with flotation scum and further dewatered by smaller size dewatering equipment. It is estimated that such a modification of keeping the dilute wastes separated from already concentrated wastes, for example, in Racine, WI, may provide as much as 30% to 40% reduction in the total cost of sludge treatment estimated earlier. Furthermore, in any actual system, the presence of grit or inorganic matter is expected to be significant and separate means of removing grit may be required in any CSO residual handling treatment facility.

From the treatment feasibility test results, generally it was shown that centrifugation or vacuum filtration were both applicable for dewatering after sludge thickening by gravity or flotation thickening. However, when overall results were compared based on performance, cost and area requirements, centrifugation was found to be the optimum dewatering method for all physical and physical/chemical residuals except alum treated San Francisco sludge and the biological sludges. Centrifugation alone or in combination with gravity or flotation thickening offers several other advantages that must be kept in mind in the final selection of an optimum dewatering step at any specific CSO treatment site:

1. Centrifugation is quick to start up and shut down in the field for intermittent uses in line with unpredictable timing of CSO occurrences.

2. The process is less sensitive to flow and concentration changes and can be geared for various applications in a short time. This can provide optimum utilization of the equipment even during dry-weather periods.

3. It can be automated to reduce labor costs. Savings in chemical costs are also possible because chemical conditioning is not required in all cases as for vacuum filtration. Furthermore, the power costs for equipment operation are also lower compared to vacuum filtration.

4. Centrifugation requires less space and because of its compactness can be easily mounted on portable equipment which may then be utilized at a number of CSO outfall treatment locations in a metropolitan area.

Because of the above advantages and only limited number of sites that utilize biological treatment for combined sewer overflows, it is recommended that additional development work be continued on centrifugation treatment of CSO sludges with and without gravity or flotation thickening. The centrifuge equipment, both scroll and basket type units, should be evaluated at several CSO treatment locations. This may best be accomplished by using a portable treatment unit and utilizing it for a 6 to 8 week period at each site. The costs developed during this study should be re-evaluated and demonstrated based upon the operational data developed in Phase II. Furthermore, the organics making up the volatile solids in the CSO sludges may be far more putrescible than digested sludges and most probably will require stabilization prior to ultimate land disposal. On-site digestion facilities such as anaerobic digestion are not considered to be appropriate for CSO sludges because of the quick on-off characteristics of CSO treatment. However, stabilization by other methods such as lime stabilization may be appropriate and necessary prior to the ultimate disposal of the CSO sludges. These ultimate disposal considerations should be investigated and evaluated in detail in Phase II.

However, it should be noted that the ultimate choice of such sludge treatment concepts is expected to be site specific. The selection of the final treatment method must be based on treatability tests at the specific sites under consideration since no one method of handling and/or treatment would be applicable to every situation.

SECTION IX

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APPENDIX A
SITE DESCRIPTIONS

1. HUMBOLDT AVE., MILWAUKEE, WI

Dry-Weather Treatment

Two dry-weather treatment plants serve the 60,704 ha. (149,888 ac.) area within the limits of the Milwaukee Metropolitan Sewerage District. The older of these plants (Jones Island) serves 16,155 ha (39,888 ac) and provides secondary treatment for flows up to 757,000 cu m/day (200 mgd). The South Shore plant has primary treatment and is capable of treating a 1,211,200 cu m/day (320 mgd) flow. New secondary treatment facilities capable of treating 454,200 cu m/day (120 mgd) were completed at the South Shore plant in 1974. Following is a brief description of each of these plants (41).

Jones Island Treatment Plant - All sewage entering the Jones Island plant is passed through mechanically cleaned bar screens to remove the coarse contents such as garbage, rags, and wood from the raw wastewater flow. The screened sewage then enters degritting chambers where the velocity is reduced to approximately one foot per second. There are eight grit chambers 2.4x2.4x27.4m (8x8x90 ft) long. The flow is regulated by individually controlled gates placed at inlet and outlet points.

The sewage flows from the grit chambers to the fine screen house. The sewage passes through a series of rotary drums having 0.24 cm(3/32 in.) slots, continuous across the face of the drum. Solids too large to pass through these slots are brushed off of the drums and on to a belt conveyor. The screenings are then conveyed to a collection hopper and pneumatically ejected to the incinerator building where they are incinerated along with the coarse screenings and grit. Approximately 54,400 wet kg (60 wet tons) of these materials are incinerated each day.

Screened sewage flows from the fine screen house into mixing channels where controlled columns of activated sludge are applied. Mixing with air continues in feed channels until this mixture reaches the aeration tanks where biological treatment takes place. The aeration tanks have ridge and furrow type aeration and provides two way reverse flow. The aeration tanks are designed to aerate the mixed liquor for an average period of six hours.

Activated sludge is removed by quiescent settling. Both Dorr and Tow-Bro type clarifiers are used for final sedimentation. The settled sludge is withdrawn from the bottom of the clarifiers and the effluent is discharged to Lake Michigan.

A portion of the sludge is returned to the incoming sewage for seeding. The remaining increment is conditioned with ferric chloride and dewatered by vacuum filtration on any of 24 vacuum filters at the plant. The filter cake has a moisture content of about 83%.

After vacuum filtration, the sludge is conveyed to an indirect-direct counter-flow rotary drum type dryer. These dryers reduce the moisture content of the sludge to about 5%. The dried solids are then crushed and screened and sold as fertilizer.

South Shore Treatment Plant - The sewage enters the South Shore Plant through 2.54 cm (1 in.) mechanically cleaned bar screens. Solids removed from the screens are hand-fed to hammermill type grinders and returned to sewage flow.

After screening the sewage flows into the grit basins. Flow through the grit basins proceeds at about 0.3048 m/sec. (1.0 fps). The grit is removed from the chambers and washed. Cleaned grit is stored and hauled away by truck to a sanitary landfill or an incineration site. The organics washed from the grit are returned to the sewage flow.

The sewage then flows to the distribution chambers from which it is routed to the settling basins. The sixteen tanks provide a detention period of 3 hours at 227,100 cu m/day (60 mgd). When the secondary treatment plant is added and the flow is upgraded to 454,200 cu m/day (120 mgd) the settling period will be 1.5 hours. Straight line mechanical sludge collectors convey the sludge to cross collectors which, in turn deposit the sludge in a vault. The effluent overflows from the settling tanks and is dispersed to Lake Michigan.

Sludge from the vault or directly from the hoppers, is pumped by four positive displacement pumps to the digestion tanks. The total volume of the digestion tanks is 44,800 cu m (1,600,000 cu ft). The sludge temperature is maintained at 29.4 to 32.2 ^{o}C (85^{o} to 90^{o}F) by heaters which can burn either natural gas or digester gas.

Sludge flows from the digesters by gravity and is pumped to four lagoons. The lagoons are approximately 118.9 m square (390 ft square) with a minimum depth of 4.6 m (15 ft) and have a total capacity between 224,000 and 280,000 cu m (8 and 10 million cu ft). They are estimated to be adequate for 20 years without removal of sludge.

Wet-Weather Treatment

Humboldt Avenue, Milwaukee, WI (42) - The detention tank at Humboldt Avenue receives the combined sewer overflow from a 205 ha (570 ac). drainage area containing approximately 33.8 km (21 miles) of combined sewers and representing 1/27 of the combined sewer area in Milwaukee. The area is residential and commercial in character and contains primarily combined sewers with a few separate storm sewers intercepted within the project area. Two relief sewers which traverse the area and the Milwaukee Sewerage Commission's intercepting sewer remove from the system a substantial amount of the total combined sewage generated within the study area before it reaches the detention tank.

Flow to the tank is by gravity, through a 198 cm (78 in.) sewer. Upon entering the tank inlet channel, the flow passes through a mechanically cleaned 3.8 cm (1.5 in.) bar screen. All solid material retained on the screen are deposited in a 2.25 cu m (3 cu yd) portable refuse container.

Seven rotary mixers are located within the tank. Only one of these seven mixers is equipped with a two-speed motor drive and is operated at low speed prior to and during periods of tank overflow to distribute chlorine for disinfection. Facilities for pre and post-chlorination of the CSO are provided. The pre-chlorination diffuser header is located just ahead of the tank inlet and runs across the inlet channel. The post-chlorination diffuser distributes chlorine across the entire 22.9 m (75 ft) width of the tank at a point about 3.7 m (12 ft) above the tank floor and 53.9 m (177 ft) from the overflow weir.

Combined sewer overflows in excess of the tank capacity (3.9 million gal.) [14761.5 cu m] during periods of overflow are discharged from the tank to the Milwaukee River. After the overflow has subsided, all mixers are activated to resuspend settled solids. The resuspended tank contents are then pumped to the Jones Island Treatment Plant.

2. CAMBRIDGE, MA

Dry-Weather Treatment

There are two dry-weather treatment plants serving a 165 ha (407.5 ac.) drainage area. These plants are the Deere Island Treatment Plant, 1,298,255 cu m/day (343 mgd) and the Nut Island Treatment Plant, 1,286,900 cu m/day (340 mgd). The following is a description of these plants (38).

Deere Island Treatment Plant - This treatment plant has been in operation since June, 1968 and serves 22 communities with a population of approximately 1,400,000. Seven pumping stations are located throughout the contributing area.

The facilities include three remote headworks which are connected to the main pumping facility by two deep rock tunnels. The tunnel from the Ward Street and Columbus Part Headworks is approximately 11.3 km (7 miles) long. An additional facility, the Winthrop Terminal Facility, located on the main plant site, provides sewerage service for local areas and is connected directly to the Deere Island Plant through a separate direct pump discharge. Each headworks provides screening and grit removal for the sewage flowing through the headworks.

Treatment at the Deere Island Plant starts with pre-chlorination and pre-aeration. The pre-searation tankes place in two channels, each 121.9x6x4.3 m (400 x 20 x 14 ft), with a detention time of 10 minutes. The flow then passes to the sedimentation tanks which have a detention time of 60 minutes. The effluent is then post-chlorinated and discharged through two marine outfalls located in approximately 15.2 m (50 ft) of water in Boston Harbor.

The treatment of raw sludge is accomplished by separate sludge thickening prior to high rate digestion. Three primary digesters, equipped with fixed cover, internal heaters, and draft tube mixers, have a sludge recirculation system via a common manifold. A fourth digester, equipped with a fixed cover and separate liquid recirculation system, serves as a storage tank, receiving all primary digested solids and overflow to allow controlled discharge of digested material to the sea during periods of outgoing tides.

Nut Island Treatment Plant - The Nut Island Plant has been treating waste from 21 cities and towns with a population of 775,000 since 1962.

The treatment processes include pre-chlorination, coarse screening and grit removal for incineration, pre-aeration of the effluent for 20 minutes, primary sedimentation, and post-chlorination of plant effluent prior to discharge through a 152.4 cm (60 in.) outfall pipe some 1,828.8 m (6,000 ft) off shore in deep tidal water.

The treatment of raw sludge is accomplished by modified high rate digestion. Two primary tanks, which have fixed covers, and one primary tank with a floating cover are equipped to provide continuous recirculation of the tank contents. A secondary digestion tank of the same capacity is equipped with a floating cover and supernatant drawoff. The digested sludge is disposed of through a 30.5 cm (12 in.) submarine pipe line which extends a distance of 6.8 km (4.2 miles) from the treatment plant into deep tidal water on the south side of President Road.

Gas produced by the digestion process is the principal source of fuel for all plant power and heating purposes. One or more of the six waste gas burners, provided for burning excess gas, are in continuous use.

Wet-Weather Treatment

Cottage Farm, Cambridge, MA (43) - The Cottage Farm Combined Sewer Detention and Chlorination Station is located on the north bank of the Charles River just upstream of the Boston University (B.U.) Bridge in Cambridge, MA. The Cottage Farm Station diverts, stores and treats excess CSO which cannot be carried to Deere Island Sewage Treatment Plant from the communities in the Charles River sewer system. It is one element of the Metropolitan District Commission's comprehensive sewage system expansion program to reduce pollution in the Charles River basin.

The outfall from the facility is located so as to provide effective discharge and mixing of the effluent with the river water. Flows up to 2.1 times the 1986 dry weather flow, or 552,610 cu m/day (146 mgd) can be carried to the Ward Street Headworks, and from there to the Deere Island Sewage Treatment Plant. Flows in excess of 552,610 cu m/day (146 mgd) are diverted to the Cottage Farm Detention and Chlorination Station. The design capacity, 882,283 cu m/day (223 mgd), of the Cottage Farm Facility was established by the capacity and need for diversion of the Charles River Sewer System at the B.U. Bridge. Any overflows from these systems are discharged through relief outlets into the river basin.

During a rainstorm, when the relief sewers contributing flows to the Cottage Farm Station reach their individual downstream capacity, they become surcharged. The flow enters the inlet channel to the plant and activates the plant when the flow depth reaches 35.6 cm (14 in.). As the flow enters the plant, it is directed to three channels, each designed for 454,200 cu m/day (120 mgd). In the channel, the flow passes through a coarse bar screen followed by a fine bar screen. The coarse bar screen has openings of 8.9 cm (3.5 in.) and the fine bar screen has an opening of 1.3 cm (0.5 in.). Both of these screens are mechanically cleaned.

From the screen chambers, the flow enters the wet wells from where it is pumped into one of the discharge channels. Chlorine is added at the discharge side of the pumps. From the discharge channel, the flow is divided into six diversion channels which distribute the flow into six detention tanks. Flows in excess of the detention tank's capacity discharge into the Charles River Basin through a 243.8 cm (96 in.) outfall.

After an activation, the detention tanks are dewatered by gravity through a pipe in the bottom of each tank and drained back to the North Charles Relief Sewer. The residual waste is ultimately disposed of at the Deere Island Treatment Plant. The screen channel is cleaned by recirculating the chlorinated flow retained in the first detention tank to the inlet structure and then back through the channels into the wet well from where it is pumped to the North Charles Relief Sewer. The detention tanks, pump discharge channel, wet well, and screen room are then manually washed by a maintenance crew.

3. RACINE, WI

Dry-Weather Treatment (44)

The treatment of wastewater at Racine, WI is accomplished by a full primary treatment, a 45,420 cu m/day (12 mgd) secondary treatment plant, chlorination, sludge digestion and vacuum filtration. The average flow to the plant for 1970, 1971, and 1972 was 79,257.9 cu m/day (20.94 mgd).

The wastewater flows through a mechanically cleaned bar screen to four comminutors, each rated 45,420 cu m/day (12 mgd). The wastewater then flows to the degritting chambers which consist of three grit channels. Two of these are 2.9 m (9.5 ft) wide and 12.2 m (40 ft) long and the third is 5.9 m (19.5 ft) wide and 12.2 m (40 ft) long. All channels have a flow depth of 0.9 m (3 ft) and are provided with mechanical scrapers. The grit is removed from the grit basins by the scrapers. A screw type cross conveyor and screw type grit washer remove and further cleanse the grit for satisfactory disposal as fill materials. Four primary clarifiers, each 10.5 (34.5 ft) wide and 41.8 m (137.3 ft) long can hold a total of 4,920.5 cu m (1,300,000 gal.). Mechanical scrapers push the sludge to hoppers from where it is sent to digesters. Clarified effluent flows over weirs to the secondary plant. The sludge from the primary treatment goes to a 3,785 cu m (1,000,000 gal.) primary digester. A gas recirculation system is provided for mixing of the sludge, and a heat exhcnager is provided for heating the sludge. The temperature is maintained at 35°C (95°F). During this process methane gas is produced and utilized as a fuel supply for the engines and boilers. After primary digestion, the sludge is pumped to the secondary digesters. The total volume of the secondary digesters is 3,785 cu m (1,000,000 gal.). The digested sludge is then pumped to the vacuum filtration system.

Secondary treatment consists of an activated sludge type treatment system utilizing the Kraus process. Four aeration tanks having a total volume of 8,516 cu m (2,250,000 gal.) handle an average of 3,797 cu m/day (12 mgd) of settled wastewater. The tanks can be operated in several alternate modes. Settled wastewater can be introduced into the tanks, together with return activated sludge. The contents are then mixed with air provided through diffuser tubes. This air also serves as a supply of oxygen for the microorganisms. The resulting mixed liquor is transferred from the aeration tanks to two final settling tanks each having a volume of 1,892.5 cu m (500,000 gal.) and a detention time of 2 hours. The effluent is conveyed to a chlorine contact tank prior to discharge into Lake Michigan.

The residual sludge from the various operations is dewatered by vacuum filtration. Two 3 m (10 ft) by 3 m (10 ft) vacuum filters are utilized. Each filter has its own conditioning tank where chemicals are added to aid coagulation and improve filterability. Chemicals utilized are lime and ferric chloride. The filter cake is disposed of, by truck, to a land fill site.

Wet-Weather Treatment (11)

The entire combined sewer system for the City of Racine covers 284 ha. (700 ac.) of the central city. Two satellite treatment plant units are provided at the (CSO) outfalls to treat a maximum flow of 219,500 cu m/day (58 mgd from a contributing area of 190 ha. (469 ac.), or 67 percent of the entire combined sewer area.

The treatment units consist of two basic operations: screening followed by dissolved-air flotation. The CSO enters the site wet well and passes through a mechanically cleaned bar screen to a spiral screw pump. The pump discharges into a channel leading to the drum screen. The screen employed to remove suspended matter in the flow has 297 micron openings (50 mesh). When headloss through the screens become excessive, backwash water is pumped from the screen chamber and sprayed on the outer surface of the screens to flush solids from the inner surface. These solids along with the backwash are collected in a hopper and flow by gravity to a screw conveyor which delivers them to the sludge tank where they are held until the overflow event is over.

The CSO then flows to the flotation tanks where it is blended with air saturated pressurized flow. The floated sludge is periodically skimmed from the top of the tanks and deposited in the screw conveyor which delivers it to the sludge tank.

This system does not employ effluent recycle for air mixing and pressurization. Instead, approximately 20 percent of the raw flow is pressurized for this purpose. Ferric chlorine and polymer are added to the raw CSO to facilitate the coagulation of particulate matter before flotation. Ferric chloride is added in the wet well ahead of the spiral screw pump. Polymer is added in the drum screen effluent channel. Chlorine is also added in the drum screen effluent channel for disinfection purposes.

The sludge holding tanks are drained back to the city sewer system when the water level in the sewer has decreased to the point where the tank contents can be drained without causing an overflow at a point farther downstream in the interceptor sewer.

4. HAWLEY ROAD, MILWAUKEE, WI

Dry-Weather Treatment

The dry-weather treatment plant for Milwaukee, WI has been previously described in conjunction with the Humboldt Avenue detention and chlorination facility.

Wet-Weather Treatment (20)

The Hawley Road screening/dissolved-air flotation system is a 18,900 cu m/day (5 mgd) pilot demonstration treatment facility. The combined sewer area served is 200 ha (495 ac.) and is a completely developed residential area in one of the older sections of thecity. The treatment site is located at one of 110 combined sewer overflow points in the Milwaukee area. The entire combined sewer area in the City of Milwaukee is 70 sq km (27 sq mi).

The demonstration unit consists of two basic operations: screening followed by dissolved-air flotation. The CSO passes through a bar screen and then enters the drum screen. The water passes through the screen media and into a screened water chamber directly below the drum. The drum rotates and carries the removed solids to the spray cleaning system where they are flushed into a hopper inside the screen and washed to a drain pipe that discharges to the city sewer system.

The screened CSO then flows to the head end of the flotation tank where it is mixed with the air saturated pressurized flow coming from the pressurization tank. A portion of the flotation tank effluent or the raw CSO can be used as the source of pressurized flow. The floated scum is scrapped off the flotation tanks and flows by gravity to the city sewer system.

Provisions are also made in the system for the addition of ferric chloride and polymer to the flow before it enters the flotation tank similar to the Racine CSO treatment system described earlier.

5. SAN FRANCISCO, CA

Dry-Weather Treatment (45)

The San Francisco Bay metropolitan district has a total drainage area of 11,340 ha (28,000 ac) of which 9,720 ha (24,000 ac) drains to public sewer systems while the remainder drains to private sewer systems. Sanitary flows from both public and private sewers are treated at one of the three waste treatment plants in the Bay area. The domestic and industrial flows are estimated to be 138 million cu m (36.5 billion gal.) per year while the storm-water runoff is estimated to be 33 million cu m (8.8 billion gal.) per year. Of this total flow of 171 million cu m (45.3 billion gal.) per year, only 149 million cu m (39.3 billion gal.) can be handled through the dry-weather treatment facilities. The remainder of 22 million cu m (6 billion gal.) per year is discharged to the San Francisco Bay as combined sewer overflow. A brief description of the three dry-weather treatment plants serving San Francisco area follows:

North Point Plant - The plant serves a tributary area of 3037 ha (7500 ac.) of combined residential. commercial and industrial land uses. The treatment consists of pre and post-chlorination, pre-aeration and primary sedimentation. The treatment capacity of the plant is 246,025 cu m/day (65 mgd). Any flows in excess of the plant capacity are bypassed via upstream diversion structures to the San Francisco Bay without any treatment.

Primary settling takes place in six combination pre-aeration - sedimentation tanks. Total detention time including pre-aeration at the design flow capacity of 246,025 cu m/day (65 mgd) is two hours. Under normal conditions all six tanks are in operation. About once a year each tank is taken out of service for maintenance and repair.

The North Point Plant does not include facilities for treatment of sludge. Sludge is pumped to the Southeast Plant at an average flow of 3217.3 cu m/day (850,000 gpd) and a solids concentration of about 1 percent.

Richmond-Sunset Plant - The plant serves a tributary area of 4236.3 ha (10,460 ac), most of which is residential. The plant provides primary treatment for a peak wet-weather flow of 264,950 cu m/day (70 mgd). The treatment capacity of the plant is 264,950 cu m/day (70 mgd). Any flows in excess of the plant capacity are bypassed at two separate points. The treatment consists of primary sedimentation and effluent chlorination prior to discharge to the Pacific Ocean. The residual solids are first stabilized in aerobic digestion tanks and then conditioned by elutriation and coagulation addition prior to dewatering by vacuum filtration. The stabilized-filtered sludge is then used as a soil conditioner. At the present time, the average raw sludge flow to the digesters is 378.5 cu m/day (100,000 gpd) at a solids concentration of 2.0-2.5 percent. Present cake production is approximately 1088.4 m tons (1200 tons) of dry solids per year at an average solids concentration of 25%.

Southeast Plant - This plant serves nearly 4048 ha. (10,000 ac.) of heavy industrialized areas of San Francisco and approximately 810 ha. (2000 ac) of San Mateo counties. The treatment consists of primary sedimentation and effluent chlorination. The residual solids from both the North Point as well as the Southeast plants are processed at this facility through gravity thickeners, digestors and vacuum filters after elutriation and chemical conditioning. Approximately 19,000 m tons (21,000 tons) of sludge cake is produced per year from this plant at an average solids concentration of 28%.

Wet-Weather Treatment (46)

The wet-weather treatment system, called the "Baker Street Plant", is a dissolved-air flotation system and is used for the treatment of CSO in San Francisco, CA. The treatment facility receives the drainage from 68 ha. (168 ac.) and has a hydraulic capacity of 9,084 cu m/day (24 mgd). The facility is comprised of two "modules" of 4,542 cu m/day (12 mgd) capacity and each is capable of operation independent of the other. Each module has the following key components: flotation tank equipped with sludge and scum removal systems; recycle system piped to permit intake of recycle flow from either the flotation tank at a point just under the effluent launder or from the raw influent stream; chemical feed systems for handling alum, caustic, polyelectrolyte, and sodium hypochlorite solutions; solids handling system providing for the air lifting of solids for subsequent gravity flow to a solids sump and the ultimate transfer of solids to the city sewer system.

From storm generated flows, the treatment system can receive up to 9,084 cu m/day (24 mgd); anything in excess of this flow is bypassed to the Bay. The influent flows through a bar screen and a magnetic flow meter before it is split and fed into the two flotation tanks. The effluent from these tanks is discharged into San Francisco Bay.

The system is designed such that the water needed for air saturation can be split from the influent stream or taken as recycle from the flotation tank. This water is pumped by a recycle pump into a pressurization tank. At the recycle pump, air is introduced into the stream by an air compressor.

In the pressurization tank, air-water interface is provided to obtain high rates of air solution. The pressure in the tank is maintained at the desired level by a downstream pressure reduction valve. Nominal detention time in the tank is generally about one minute. The pressurized flow is then blended with the raw flow in a mixing zone at the influent end of each flotation tank. Independent chemical feed systems, consisting of tankage, pumpage and alternative chemical introduction points, are provided. Feed pH is automatically adjusted to desired levels using caustic. Other chemicals that are utilized are alum and polyelectrolyte to aid in solids flocculation and separation.

There are two sources of sludge in this system: the solids that are floated and the solids that settle to the bottom of the flotation tanks. The floated solids are skimmed off the flotation tanks during operation and flow by gravity to a solids sump. Any settled solids at the bottom of the tank are washed to a corner of the tank and pumped to the solids sump. These accumulated solids are then pumped to a city sewage pumping station.

6. KENOSHA, WI

Dry-Weather Treatment (47)

The dry-weather treatment facilities consist of primary sedimentation with a maximum design capacity of 113,500 cu m/day (30 mgd) followed by a 87,055 cu m/day (23 mgd) conventional activated sludge system and chlorination. Raw sewage enters the plant by gravity from a 183 cm (82 in.) diameter interceptor sewer. Flows in excess of the plant capacity are diverted by a hydraulic control gate.

The raw sewage entering the plant is pumped through two grit removal facilities which operate in parallel. The discharge from the grit chamber flows by gravity to 6 primary settling basins which have a total surface area of 2,303 sq m (24,760 sq ft) and a volume of 7,213 cu m (257,600 cu ft). The maximum hydraulic capacity of the facility is rated at 113,500 cu m/day (30 mgd), resulting in surface overflow rates of 49.7 cu m/day/sq m (1,212 gpd/sq ft) and a detention time of 1.54 hours. Effluent from primary sedimentation is conveyed to the mixed liquor aeration tanks where it is mixed with return activated sludge (RAS). There are four mixed liquor tanks having a total volume of 13,328 cu m (476,000 cu ft) and an aeration time of 3.72 hours at a maximum design capacity of 87,055 cu m/day (23 mgd). The mixed liquor from the aeration tanks flows to three 25.9 m (85 ft) diameter final clarifiers, having a total surface area of 1,581 sq m (17,020 sq ft). The surface overflow rate at maximum flow is 55.1 cu m/day/sq m (1,350 gpd/sq ft) and the detention time (not including RAS) is 1.32 hours. The waste activated sludge (WAS) from the final clarifier is thickened by means of two dissolved-air flotation units having a total capacity of 8,080 kg (20,000 lb) of solids per day.

The effluent after final clarification is chlorinated in a contact tank having a volume of 605.6 cu m (160,000 gal.). At a flow of 113,550 cu m/day (30 mgd) the detention time in this tank is 7.7 minutes plus an additional 7.3 minutes in the discharge conduit to Lake Michigan.

Wet-Weather Treatment (12)

The process for treating combined sewer overflows at the Kenosha demonstration site is contact stabilization. The main difference between the demonstration project and normal contact stabilization plant is the periodic usage of the system. Due to this, provisions for borrowing waste activated sludge from the dry-weather plant were made. This provision was never utilized because there was always sufficient volume of sludge in the stabilization tank, prior to system deployment, to provide a sufficient reaeration time during operation.

The original grit basins had a maximum hydraulic capacity of 34,056 cu m/day (9 mgd) and would not be able to handle a higher loading. In order to provide more grit removal capacity, an unused mixing and flocculation basin was converted into a grit basin. The new grit basin is conveniently located between the pump room and the site for the contact stabilization tanks. The modified tank is designed to handle a flow of 75,700 cu m/day (20 mgd) at a velocity of 0.06 m per second (0.2 fps). The floor of the tank is sloped so that all extremities drain to the middle 6m (20 ft) of the west wall. At this location a telescoping valve and a screen well are installed to drain the tank after a run. The deposited grit on the floor of the tank is flushed to the west wall where it is suction pumped to a truck and hauled to a landfill site.

The contact and stabilization tanks are located on a structure which is divided by concrete walls into four compartments. Two contact tanks are designed to handle a maximum flow of 75,700 cu m/day (20 mgd) and a stabilized sludge flow of 11,355 cu m/day (3 mgd) for a 15 minute contact period. This requires a volume of approximately 946 cu m (250,000 gal.). The contact tanks have a volume of 620.7 and 304.5 cu m (164,000 and 80,465 gal.), with a combined volume of 925.3 cu m (244,456 gal.).

Aeration is supplied to the contact tank by means of a fixed air disperser system located along the bottom of the northern wall of the contact tank. The dispersers are supplied by the existing blower system and are capable of delivering up to 106.4 cu m/min (3,800 cfm) of air.

The stabilization tank is also divided into two tanks so that various stabilization times may be studied. Both tanks are identical, having a volume of 1,386 cu m (366,329 gal.) each. One tank may be filled without filling the other. This allows for a short stabilization time if desired. The two tanks are connected by permanent openings in the concrete wall divider 2.19 m (7.17 ft) above the floor of the tank. After this height is reached, both tanks must be filled simultaneously.

Aeration for the stabilization tanks is provided by 8 mechanical surface aerators, four in each tank. The aerators are 50 horsepower each and have a total design transfer rate of 454 kg (1,000 lb) per hour.

Two 37,850 cu m/day (10 mgd) pumps are provided to transfer the stabilized sludge to the contact tanks. This combined capacity allows up to 75,700 cu m/day (20 mgd) of stabilization sludge to be transferred, which is equal to 100 percent of the combined sewer flow. A 1,892.5 cu m/day (0.5 mgd) pump is also needed during dry-weather to transfer unused stabilized sludge to the existing thickeners. All three pumps are located on a concrete platform between the contact and stabilization tanks.

The clarifier is designed for use during both dry-weather flow and overflow conditions. During dry-weather, the mixed liquor from the existing plant is fed to the new clarifier for sedimentation. The settled sludge from the clarifier is pumped back into the existing plants sludge return system. The clarifier doubled the existing plant's clarification area.

The entire biosorption process is completely automated and is directed from a main control board. The main control board receives and sends information from and to all operations of the process. The information regulates all flow rates which in turn determine contact times, mixed liquor concentrations, stabilization times, air supply rates, and settling times. This is done by setting all variable flows as a percentage of the raw sewage flow.

During dry-weather the only activity performed by the wet-weather facility is to store waste activated sludge in the stabilization tank for a set period of time before going on to the existing thickener. The rate of wasted sludge flow from the existing treatment plant to the stabilization tank is manually set at the main control board. By allowing the tank to fill to the desired volume and then settling the flow out of the tank equal to 100 percent of the flow into the tank, a constant stabilization detention time is achieved.

7. NEW PROVIDENCE, NJ

Dry and Wet-Weather Treatment (14)

The dual use of treatment plants, using wet-weather facilities to treat dry-weather flows, is demonstrated well in New Providence. Unlike the other sites, the New Providence area has a totally separated sewer system. High infiltration/inflow conditions during periods of wet-weather may increase flows to rates as high as 10 times the dry-weather flow. To treat these flow variations while maintaining high levels of treatment, a unique trickling filter operation has been installed.

The plant is designed to handle a dry-weather flow of 1892 cu m/day (0.5 mgd) and wet-weather flows of up to a maximum of 22,710 cu m/day (6 mgd). The treatment facilities include primary clarification, trickling filtration, secondary clarification, and post chlorination. Residual sludges up to 5,678 cu m/day (1.5 mgd) are pumped to the city of Summit, NJ solids handling facilities under a "Pumping Rights" agreement.

Two comminutors are provided at the inlet facilities for shredding the coarser solids in the raw sewage. The raw sewage is pumped by low lift pumps (three at 18,925 cu m/day (5 mgd) each) to the primary settling reservoir, a 1,608.6 cu m (425,000 gal.) tank which provides the first phase of treatment at the facility. The clarifier has a two fold function: it removes organics, inorganics, scum, grease and oil from the flow and the large volume of the tank allows equalization of flow to the treatment plant. The sludge from this tank is pumped daily to the City of Summit during a period of about three hours.

One of the two filters is a plastic media filter 11 m (36 ft) in diameter and 4.4 m (14.3 ft) deep. The primary tank effluent plus the recirculated flows are distributed on the filter by a pair of distributor arms which rotate by virtue of the liquid head created in the center column to which the rotating arms are attached.

During dry-weather operation, the effluent from the plastic media filter is pumped to the high rate rock trickling filter. The rock filter is 19.8 m (65 ft) in diameter, 1.8 m (6 ft) deep and is constructed of concrete. From here the effluent flows to the final clarifier.

The final clarifier is 21m (70 ft) in diameter and has a sidewall depth of 2.4m (8 ft). The bottom scraper arms operate at about 2 revolutions per hour. During periods of dry-weather, recirculation pumps with a capacity of 3,028 cu m/day (0.8 mgd) provide the minimum hydraulic loadings for the trickling filters. The sludge at the bottom of the final clarifier flows, by gravity, to the inlet of the plant.

The unique feature of this plant is its ability to operate under a wide range of hydraulic loadings. During dry-weather the plant operates in series with the plastic filter being the lead filter. During periods of wet-weather, when the flow increases above 10,598 cu m/day (2.8 mgd), automatic transfer to parallel operation takes place and is maintained until flow drops to the series range. A portion of the total filter flow is then conveyed to the plastic media filter and the remainder to the rock trickling filter. The effluents from the two filters are combined and conveyed to the final clarifier. When in parallel operation, the second stage and recirculation pumps are automatically turned off.

The flow to each filter can be varied, either on a preset ratio basis or a preset constant flow basis. These operations can be controlled as follows: An adjustable preset constant flow to the plastic filter can be maintained automatically by the control circuit. Under this mode of operation, a constant flow is applied to the plastic media trickling filter with any excess flow discharged onto the rock media trickling filter. Similarly, an adjustable preset constant flow can be maintained to the rock media trickling filter with any excess flow applied to the plastic media trickling filter. In addition, a constant ratio of flow can be maintained between the plastic media trickling filter and the rock media trickling filter. This ratio can be set between 0.2 and 4.0, i.e., if the indicator is set at 1.0, it would indicate that both filters--the plastic and the rock--would be receiving the same flow. If the total filter flow exceeds 17,033 cu m/day (4.5 mgd), the raw sewage pumps which pump to Summit at a constant rate of 5,678 cu m/day (1.5 mgd) are automatically turned off. When the wet-weather flow decreases to 11,355 cu m/day (3 mgd), the Summit pumps are automatically turned back on. At a flow rate of 7,750 cu m/day (2 mgd), the secondary treatment system will switch automatically from parallel to series operation, resulting in the turning on of the second stage and recirculation pumps.

Under the foregoing conditions, an extreme amount of flexibility is provided in the operation of the plant for the treatment of both dry-weather and wet-weather flows.

APPENDIX B

ANALYTICAL PROCEDURES

The following analyses were performed according to Standard Methods for the Examination of Water and Wastewater, 13th Edition, 1971 (SM) (6) and Methods for Chemical Analysis of Water and Wastes, 1971, EPA Water Quality Office (WQO), Cincinnati, Ohio (7).

pH	WQO, p. 230
Total Solids	WQO, p. 280
Total Volatile Solids	WQO, p. 282
Suspended Solids	WQO, p. 278
Volatile Suspended Solids	WQO, p. 282
BOD	SM, p. 489
TOC	WQO, p. 221
Total Phosphate	WQO, p. 239
Kjeldahl Nitrogen	WQO, p. 149
Nitrate	SM, p. 458
Nitrite	WQO, p. 195
Metals Zn, Pb, Cu, Ni, Cr	Digestion - WQO, p. 88 recommended by the manufacturer for the instrument used (Perkins-Elmer Model 403).
Mercury	Digestion - Nitric acid reflux procedure (see below). Analysis: Perkin-Elmer Mercury Analysis System Operating Directions 303-3119.
Density	Pycnometer method (wide mouth pycnometer)
Heat Value	Instructions for 1241 and 1242 Adiobatic Colorimeters, Manual No. 142, Parr Instrument Company, Moline, IL
Pesticides and PCB's	Details of the pesticide analytical procedure are included later in this appendix.
Soluble Parameters	Samples were filtered through 0.45 micron membrane filters to remove suspended solids in preparation for measurement of soluble parameters.

Nitric acid reflux digestion procedure for mercury - A suitable sample volume was placed in a 250 ml round bottom flask and 10 ml of concentrated nitric acid was added. The flask was then connected to a reflux condensor (about 60 cm in length) and heated with a heating mantle causing the acid to reflex gently. The mixture was heated for two hours before allowing it to cool at room temperature. The cooled mixture was washed down in the column with about 60-70 ml of distilled water. The sample was then filtered through Whatman No. 42 paper to remove insoluble material and the filtrate was made up to 100 ml with distilled water. A suitable aliquot was then analyzed for mercury.

PESTICIDE ANALYSIS

Introduction

The method described here was used for the extraction and isolation of organochlorine pesticides and certain polychlorinated biphenyl (PCB) mixtures from stormwater and combined sewer overflow sludges. This method is based on EPA approved procedures with slight modifications to adapt it to CSO sludges. The limit of detection was 1 µg/l for Arochlor related PCB's and the following organochlorine pesticides: BHC, lindane, heptachlor, aldrin, heptachlor epoxide, dieldrin, endrin, Captan, DDE, DDD, DDT, methoxychlor , endosulfan, dichloran, mirex, pentachloronitrobenzyene and trifluralin.

The selected cleanup procedures permitted the analyst to eliminate certain anticipated interferences and allowed for separation of analogs of Arochlor #1254, #1260, #1262, #4465, from organochlorine pesticide.

Summary

PCB's and organochlorine pesticides were coextracted either by liquid-liquid extraction or for samples of high solids by mixing with anhydrous Na_2SO_4 and soxhlet extraction. A combination of the standard Florisel column cleanup and silicic acid column chromatography were employed to separate PCB's from organochlorine pesticides (48). Identification was made with a gas chromatograph equipped with an electron capture detector through the use of two or more unlike columns. Further confirmation by chemical modification using a microscale alkali treatment was used as recommended in the literature (49).

Interferences

1. All glassware, solvents, reagents, and sampling hardware must be demonstrated to be free of interferences under the conditions of analysis. Therefore, all glassware was fired at 230°C after Lamberton et al. (50).

2. Organochlorine pesticides and PCB's are mutually interfering. The silicic acid column cannot separate Arochlors #1221, #1242, #1248, #5442 and #5460 completely from DDT and its analogs. (Early eluting peaks from the Arochlors may occur in the polar eluate). For this reason the use of the chemical modification confirmating technique was utilized as recommended in the literature (49).